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(71) Applicant: **INTERNATIONAL BUSINESS  
MACHINES CORPORATION**  
Old Orchard Road  
Armonk, N.Y. 10504(US)

(72) Inventor: **Barbee, Steven George**  
RD 1, Box 241 Hollow Road  
Dover Plains, New York 12522(US)

Inventor: **Chapple-Sokol, Jonathan Daniel**  
12 Homer Place

**Poughkeepsie, New York 12603(US)**

Inventor: **Conti, Richard Anthony**  
47 Foxwood Circle

**Mount Kisco, New York 10549(US)**

Inventor: **Kotecki, David Edward**

**37 Sylvian Lake Road**

**Hopewell Junction, New York 12533(US)**

(74) Representative: **Louet Feisser, Arnold et al**  
**Trenité Van Doorne European Patent**  
**Attorneys P.O. Box 75265**  
**NL-1070 AG Amsterdam (NL)**

(54) **LPCVD reactor for high efficiency, high uniformity deposition and a method of such deposition.**

(57) An injector with a convex wall surface facing the susceptor directs vapor toward a wafer held by a susceptor producing a generally laminar flow across the surface of the wafer that in combination with the

convex wall surface prevents formation of recirculation cells in the region between the wafer and the injector.

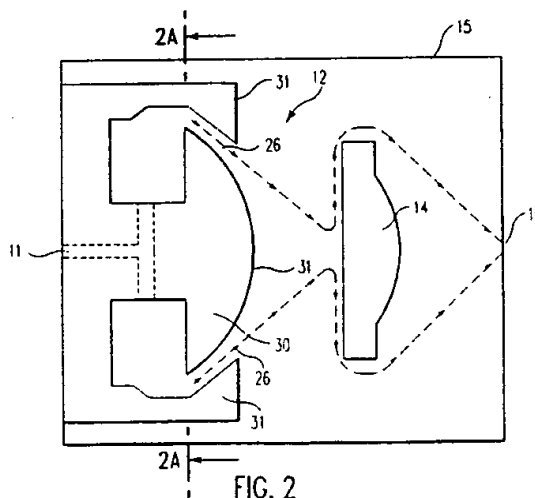


FIG. 2

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CONVEX

The present invention generally relates to an improved apparatus for chemical vapor deposition, and more particularly to an improved injector for use in such apparatus.

Chemical vapor deposition (CVD) and low pressure chemical vapor deposition (LPCVD) are well known and widely used processes for forming thin films in the semiconductor industry. Figures 1 and 1A illustrate one type of prior art apparatus for forming CVD and LPCVD films on semiconductor wafer surfaces, such films as aluminum oxide ( $\text{Al}_2\text{O}_3$ ) or tungsten films for example. In this prior art apparatus, a single injector indicated by the general reference numeral 12 is located directly in front of a susceptor 14 and injects a vapor into a chamber 15. Undeposited vapor exists through a port 16 on the opposite side of the susceptor from the injector 12.

The injector 12 has a generally unrestricted angular passage 18 through which vapor flows from a plenum 20 into the chamber 15. A passage 11 connects the plenum to an external vapor supply. The passage 18 is formed between an outer ring 22 and a central cylindrical member 24 that has a flat surface 25 forming a wall in front of the susceptor 14. The outer edge of the passage 18 is co-extensive with the outer periphery of the wafer held by the susceptor 14. The dashed arrows in the figure show generally the vapor flow path that applicants have determined exist for this prior art design, including recirculation cells.

The apparatus of the type illustrated in Figure 1 can exhibit certain shortcomings: namely, poor film uniformity across the surface of a single wafer; possible particulate generation; low vapor reaction efficiency; and low film deposition rates. Additional prior art reactors and their injectors are disclosed in the following U.S. patents.

U.S. Patent No. 4,807,562, to Sandys, discloses a chemical vapor deposition (CVD) reactor including a vertically mounted multi-sided susceptor with means to adjust the gas flow across the width of each susceptor face.

U.S. Patent No. 4,909,914, to Chiba et al., discloses a CVD reaction apparatus which comprises a flow control system provided with a convergent-divergent nozzle.

U.S. Patent No. 4,989,541, to Mikoshiba et al., discloses a thin film forming apparatus including, in addition to a material gas nozzle, a control gas nozzle for jetting a control gas flow which encircles a material gas flow jetted from the material gas nozzle against a substrate supported in a reaction chamber, so as to shape the material gas flow into the form of a beam.

U.S. Patent No. 4,993,358, to Mahawili, discloses a chemical vapor deposition (CVD) reactor and method wherein a chamber, preferably con-

figured for receiving a single wafer as a deposition substrate, has multiple gas inlet orifices and exhaust ports which are independently adjustable for dynamically varying and controlling directionality of local gas flow vectors toward and past the deposition substrate.

An object of this invention is the provision of an improved injector for use with CVD and LPCVD systems of the type generally illustrated in Figure 1; an injector that provides improved uniformity of deposited film across the surface of a single wafer. Further objects of the invention include the provision of an injector that provides improved reaction efficiency, faster film deposition rates and elimination of recirculation cell formation.

Briefly, this invention contemplates the provision of an injector with a convex wall surface facing the susceptor. The injector directs the vapor toward a wafer held by the susceptor at oblique angles with respect to the wafer surface, producing a generally laminar flow across the surface of the wafer that in combination with the convex wall surface prevents formation of recirculation cells in the region between the wafer and the injector. Such recirculation cells produce regions in the chamber where the residence time of the vapor in the reactor is longer than average, leading to non-uniform film thickness and particulate generation.

The foregoing and other objects, aspects and advantages will be better understood from the following detailed description of a preferred embodiment of the invention with reference to the drawings, where like reference numerals are used to identify like parts in the various views and in which:

Figure 1 is a schematic view, with parts in section, of prior art CVD and LPCVD apparatus. Figure 1A is a sectional view along the line A-A of Figure 1.

Figure 2 is a view similar to Figure 1 showing an injector in accordance with the teachings of this invention. Figure 2A is a schematic sectional view along the line A-A of Figure 2.

Figure 3 is a schematic view of another embodiment of the invention and Figure 3A is a view of the injector as viewed head-on from the susceptor.

Referring now to Figure 2 and Figure 2A, in accordance with the teachings of this invention the injector 12 has a passageway 26 which directs the vapor at an oblique angle with respect to the susceptor 14. The angle of incidence at which the passage directs the vapor toward the surface of the susceptor is preferably in a range between  $20^\circ$  and  $70^\circ$ . The passageway 26 restricts vapor flow relative to the prior art design, thereby increasing the flow velocity, although for most applications the flow parameters are such that the flow remains subsonic. A central generally mushroom shaped

member 30 in combination with an outer ring 31 forms an annular passage 26 that directs flow toward the center of the wafer. Member 30 has a convex, spherical surface 31 facing the susceptor 14 with the projection of surface 31 onto the circumference of a wafer upon which a film is to be deposited. This convex surface eliminates vapor recirculation cells in the chamber in front of the wafer, thereby preventing a buildup of particles in front of the injector and providing uniform residence time of vapor in the wafer surface area with a resultant film uniformity. The dotted arrows indicate the dominant vapor flow path.

Figure 3 and Figure 3A illustrate an alternate embodiment of the invention. Here, the convex surface 31 has a plurality of passages 36 through it for directing vapor toward the susceptor 14. In the embodiment shown in the drawing, some of the passages 36 direct vapor in a direction normal to the surface of a wafer held by the susceptor and other passages 36 direct vapor in a direction oblique to the wafer surface. Alternative arrangements are possible. All of the passages 36 may direct vapor in a direction normal to the wafer surface or all of the passages may direct the vapor obliquely with respect to the wafer surface. As best seen in Figure 3A, in this particular embodiment the passages are arranged in concentric circles, although other patterns may be used if desired.

While the invention has been described in terms of a single preferred embodiment, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

#### Claims

1. A chemical vapor deposition reactor comprising in combination:  
an injector disposed in a chamber opposite a susceptor upon which a wafer is supported during chemical deposition of film from a vapor injected into said chamber from said injector, said injector having convex surface facing said susceptor; said injector having an orifice directing vapor toward said wafer at an oblique angle with respect to the surface of said wafer.
2. A chemical vapor deposition reactor as in claim 1, wherein said convex surface is spherical and the projection of said convex surface on said susceptor is substantially co-extensive with the periphery of said wafer.
3. A chemical vapor deposition reactor as in claim 1 or 2, wherein said orifice is an annular ring substantially coincident in extent with the peripheral edge of said wafer.
4. A chemical vapor deposition reactor as in any of the preceding claims, wherein said orifice includes a plurality of passages disposed in a pattern on said convex surface.
5. A chemical vapor deposition reactor as in any of the preceding claims, wherein said pattern is a plurality of concentric rings.
6. A chemical vapor deposition reactor as in any of the preceding claims, wherein said oblique angle is in a range between 20 degrees and 70 degrees.
7. A chemical vapor deposition method wherein an injector disposed in a chamber opposite a susceptor upon which a wafer is supported injects a vapor into said chamber causing chemical deposition of film, said injector having convex surface facing said susceptor, whereby said injector having an orifice directing vapor toward said wafer at an oblique angle with respect to the surface of said wafer.
8. A chemical vapor deposition method as in claim 7, wherein said convex surface is spherical and the projection of said convex surface on said susceptor is substantially co-extensive with the periphery of said wafer.
9. A chemical vapor deposition method as in any of claims 7-9, wherein said orifice is an annular ring substantially coincident in extent with the peripheral edge of said wafer.
10. A chemical vapor deposition method as in any of claims 7-9, wherein said orifice includes a plurality of passages disposed in a pattern on said convex surface.

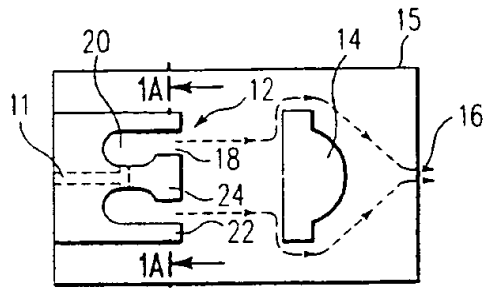


FIG. 1

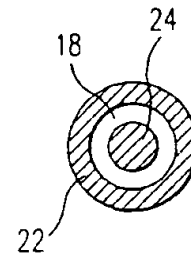


FIG. 1A

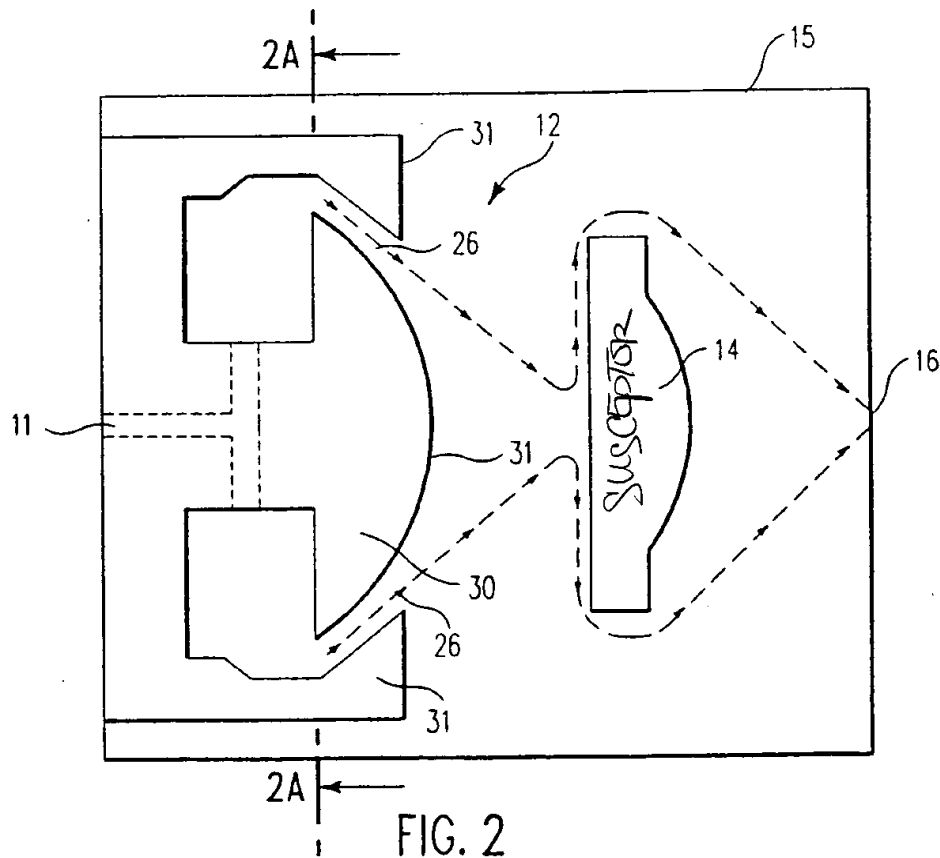
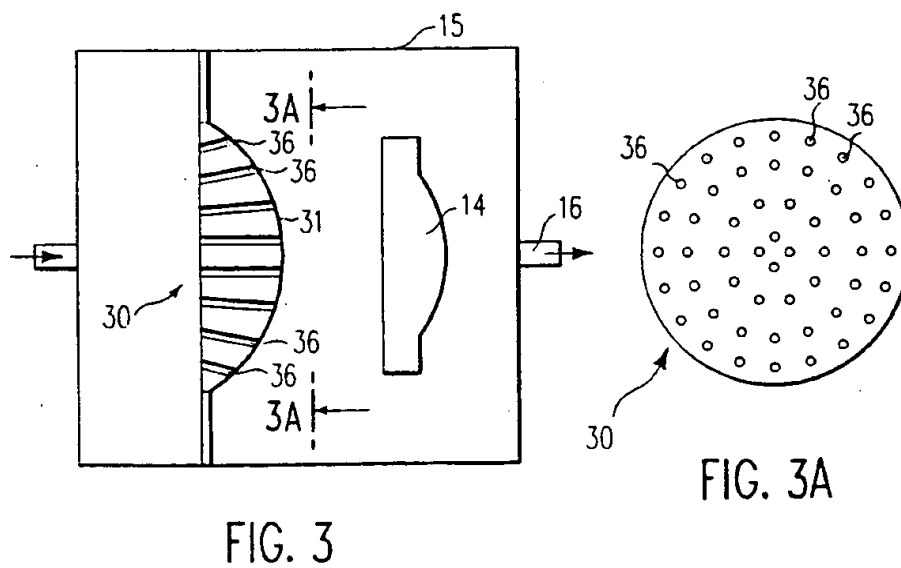
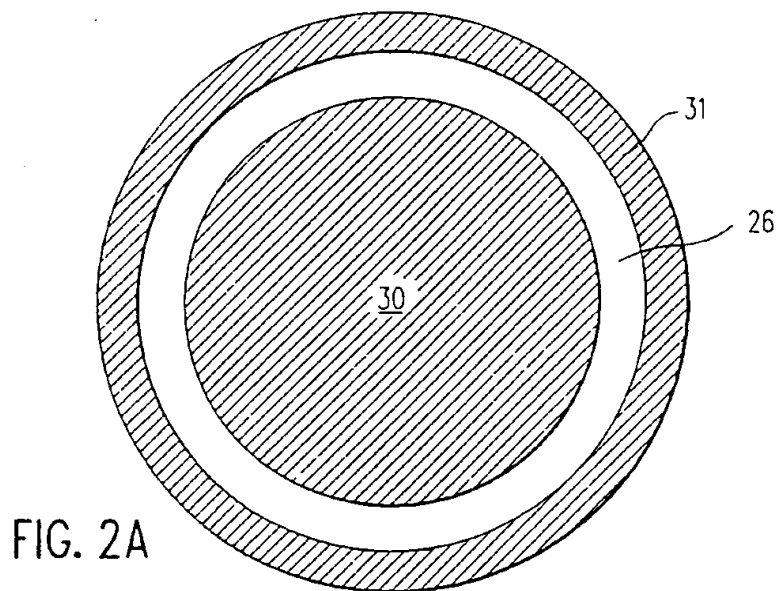


FIG. 2





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# EUROPEAN SEARCH REPORT

Application Number

EP 92 20 3171

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 8, no. 150 (C-233)(1587) 12 July 1984 & JP-A-59 054 698 ( FUJITSU KK ) 29 March 1984	1, 4, 6, 7, 10	C23C16/44 C30B25/14 H01J37/32
Y	* abstract *	2, 3, 5, 8, 9	
Y	--- US-A-4 340 568 (T. HIRAI ET AL.) * column 10, line 37 - line 50 * * column 11, line 31 - line 39; figure 8C *	3, 5, 9	
Y	--- EP-A-0 027 578 (TEXAS INSTRUMENTS INCORPORATED) * claims 1-4; figure 1 *	2, 8	
A	--- PATENT ABSTRACTS OF JAPAN vol. 7, no. 243 (E-207)(1388) 28 October 1983 & JP-A-58 132 932 ( MATSUSHITA DENSHI KOGYO KK ) 8 August 1983 * abstract *	1-10	
A	--- EP-A-0 446 596 (CARL-ZEISS-STIFTUNG) * column 5, line 27 - line 31; figures 1, 4 *	1-10	TECHNICAL FIELDS SEARCHED (Int. Cl.5)  C23C C30B H01J
A, D	--- EP-A-0 410 442 (WATKINS-JOHNSON COMPANY) * column 7, line 19 - line 31; figures 2, 5 *	1-10	
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 28 JANUARY 1993	Examiner EKHULT H.U.
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document  T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons  A : member of the same patent family, corresponding document			

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